What Research Has to Say About Designing Computer Games for Learning

Sigmund Tobias
J. D. Fletcher

Empirical research was reviewed to identify recommendations that game designers and developers could use to improve the pedagogical effectiveness of games for instruction. Findings from the research literature suggested 13 recommendations, which are discussed in this article. Distinctions between instructional games and instructional simulations and the role of games in programs of instruction are also discussed.

The popularity of computer games is evident from data published by the Entertainment Software Association (ESA), which represents the computer and video game industry in the United States. In 2006, $7.4 billion was spent on computer and video game software in this country—breaking down to eight titles sold every second of every day (ESA, 2006a). Ninety-three percent of computer game buyers and 83 percent of console game buyers were over the age of 18 in 2006.

As for game players, 53% of all Americans play computer games, their average age is 33 years old, and they have been playing for 12 years (ESA, 2006b). Thirty-eight percent of all game players are females; they play an average of 7.4 hours a week compared to 7.2 hours a week for males. Among online game players, 48 percent are males and 42 percent are females. Adults are substantially involved in computer game playing. Seventy percent of the most frequent game players are over the age of 18, as are 60 percent of the most frequent console game players. Recent news reports (Schiesel, 2007) have indicated that retired seniors are increasingly turning to video games to maintain their alertness and that the majority of these players are women.

The income generated by computer games shows no signs of abating. Games already rival movie tickets in sales, and are gaining steadily (Schiesel, 2007). More than 50% of gamers say that in 10 years they expect to play as much or more than they currently do now (ESA, 2006b).

Another sign of the popularity of computer games is that they are receiving academic attention. The International Game Developers Association (2005) reports that five years ago fewer than a dozen universities offered game related programs of study; that figure has now jumped to over 190 institutions in the United States, and another 161 worldwide.

In view of this increasingly intense activity, the training and education communities have become interested in capturing the motivation and engagement of games and using them to deliver instruction. We reviewed studies, seeking empirical, data-based findings that designers and developers could use to improve the pedagogical effectiveness of games for instruction. Games are a rapidly expanding area of investigation. Our review of this literature continues as more findings appear, but in the three years since we began, we have found that the recommendations reported here have been quite stable, suggesting that the studies cited below are representative of the field.

While we agree with Clark (2007) and Hays (2005) that the superiority of games for the delivery of instruction over other means has not been established, our focus differs from theirs. The popularity of computer games demonstrates that they will be used by students and other groups of the population. Our purpose is to make research based recommendations to designers so that games can be more useful for instructional purposes. Most of our 13 recommendations are based on research reported after 1992. For prior research, the review by Randel, Morris, Wetzel, and Whitehill (1992) should be consulted.

Games and Simulations

One difficulty in assessing the use of games for instruction is deciding, operationally, on some differences between games and simulations. Such a distinction was necessary for our review. Research on simulations used in instruction is massive in both absolute terms and relative to the research literature on computer-based games (e.g., Andrews & Bell, 2000; Blaiwes & Regan, 1986; O'Neil & Robertson, 1992; Towne, 1995). Our emphasis and interest focused on games themselves as an emerging and potentially

Sigmund Tobias is Distinguished Research Scientist, Institute for Urban and Minority Education, Teachers College, Columbia University, New York (e-mail: sig.tobias.ctr@ adlnet.gov). **J. D. Fletcher** is Research Staff Member, Institute for Defense Analyses, Alexandria, Virginia (e-mail: fletcher@ ida.org). This article is based on a paper presented at the annual convention of the American Educational Research Association, Chicago, April 2007.

Table 1. Some differences between computer simulations and computer games.

Simulations	Games
Emphasis on reality over entertainment	Emphasis on entertainment over reality
Concern with scenarios and tasks	Concern with storylines and quests
Emphasis on task completion	Emphasis on competition
May not be interactive	Necessarily interactive
Not all simulations are games	All games are simulations

important form of instructional simulation.

There are no standardized, widely accepted distinctions between games and simulations. As Table 1 suggests, we had in mind a subset of simulations—interactive, computer-based games and the learning environments they create. The table represents a rough attempt to distinguish between the world of computer simulations and the specific type of simulations that might be called computer games.

Some of the distinctions in Table 1 key on differences in emphasis. Certainly, some of our distinctions are arguable. For instance, is the popular *Hangman* game a simulation? Are Checkers, Chess, Backgammon, and Solitaire? These games have all been computerized. Both sides of the issue could be argued. However, we focused on games that cannot operate effectively without computer technology. We hope that this distinction helps clarify the type of learning experiences we sought to address.

Research Based Recommendations

The first two recommendations appear to be the most critical ones for the design of instructionally useful games.

1. *Conduct Cognitive Task Analysis to Identify the Cognitive Processes Engaged by Game and Required by Task.*

Research on computer games has found that they can affect cognitive processes. For example, they can enhance the abilities of individuals to deploy or divide visual attention (Green & Bavelier, 2003; Greenfield, 1998; Greenfield, Camaioni, Ercolani, Weiss, & Lauber, 1994; Greenfield, deWinstanley, Kilpatrick, & Kaye, 1994; Okagaki & Frensch, 1994; Subrahmanyam & Greenfield, 1994). Taking a step further, Sims and Mayer (2002) found that improvements in cognitive processes are likely to be domain specific; they may fail to generalize to stimuli and processes different from those used in games. Therefore, to assess the impact of a computer game, the cognitive processes it engages need to be identified through cognitive task analysis. Principles and procedures for conducting such analyses have been described by Crandall, Klein, and Hoffman (2006), Gott and Lesgold (2000), Hall, Gott, and Pokorny (1996), and Schraagen, Chipman, and Shalin (2000), among others.

If computer games are intended to enhance performance on tasks at work or in school, i.e., are intended to transfer to 'real-world tasks,' it is vital to identify the cognitive processes they require. Evidence has been found of transfer from games to targeted task performance (Fery & Ponserre, 2001; Gopher, Weil, & Bareket, 1994; Mayer, Mautone, & Prothero, 2002; Moreno & Mayer, 2004, 2005; Okagaki & Frensch; 1994; Subrahmanyam & Greenfield 1994). Not suprisingly, the extent of game playing appears to matter. For instance, Greenfield, Brannon, and Lohr (1994) found that long-term practice with a video game improved spatial performance, but that short-term practice did not.

In the field of laparoscopic surgery, where a tiny camera and surgical instruments are controlled by joysticks, there is evidence that use of specifically designed laparoscopic simulators improves surgical skills (Clark et al., 2005; Colt, Crawford, & Galbraith, 2001; Gallagher, Lederman, McGlade, Satava, & Smith, 2004; Gallagher, Ritter, Champion, Higgins, Fried, Moses, Smith, & Satava, 2005; Gallagher & Smith, 2003; Hamilton, Scott, & Kapoor, 2001; Pedowitz, Esch, & Snyder, 2002). It seems reasonable to expect that experience with computer games using joysticks and the like to control actions and instruments may improve the performance of laparoscopic surgeons. Recently, Rosser, Lynch, Cuddihy, Gentile, Klonsky, and Merrell (2007) found just that. They reported increases in laparoscopic surgical proficiency attributable to playing "off the shelf" video games. These data need replication, but their implications are intriguing.

Other research has found transfer from games to 'real-life' tasks. Fery and Ponserre (2001) found transfer to actual golf putting from a computer game that was specifically selected for the fidelity with which it reproduced actual putting. Brown *et al.* (1997) found gains in the self-treatment and self-reporting capabilities of diabetic patients after they had spent time playing a game that dealt with these issues. In both cases, careful analyses of the target task(s) led to design of the games.

In general, current research suggests that similarity of cognitive processes used in computer games and in real-life tasks cannot be assumed merely because the two appear to be similar. Gopher *et al.* (1994) found transfer from the *Space Fortress* game to piloting real aircraft—after Mane and Donchin (1989) revised the game to resemble actual flight with respect to complexity, attention, and cognitive load demands. However, Hart and Battiste (1992) found that assigning trainees to an off-the-shelf game (*Apache Strike Force*), also dealing with flying, had no transfer effects.

These results indicate that it is not simply the surface similarity between games and tasks that leads to transfer, but the overlap in cognitive processes engaged by both. We conclude from these studies that game design based on cognitive task analyses of both the game and the targeted tasks are essential for reliable and successful transfer from the game to 'real-world' performance.

2. *Provide Guidance.*

Swaak and de Jong (2001) proposed various types of instructional support (Tobias, 1982) that might be used to improve learning from games. The importance of such support was confirmed by research results (Moreno & Mayer, 2005; Rieber, 2005) indicating that providing guidance and stimulating reflection by explaining the reasons some answers are correct may be more useful than relying on the game experience alone.

Similarly, Greenfield, Camaioni *et al.* (1994) found that providing guidance in the form of explanations facilitated performance. An analysis of research results (Lee, 1999) confirmed these suggestions by finding that students who used simulations that included exposition of the instructional content and/or guidance learned more than students working with simulations without such forms of instructional support. It seems reasonable to expect similar results from instructional games. Renkl and Atkinson (2003) found that another form of instructional support, fading (gradually removing) the steps in examples that had been worked out for students, facilitated near and far transfer. Providing guidance and various forms of instructional support seem important in enhancing learning from computer games. Some more specifics follow.

2a. Provide Pictorial Support. Mayer, Mautone, and Prothero (2002) examined the types of guidance—verbal modeling of solutions strategies or pictorial instructional support—that might be most beneficial for students as they solve problems in a multimedia simulation game. Verbal guidance had no effect, while pictorial support did improve performance both on the game and on a transfer task (solving problems on paper similar to computer game tasks). Multimedia research (Fletcher & Tobias, 2005; Moreno, 2005) has shown that pictorial support tends to reduce the cognitive demand of tasks compared to the use of verbal information alone. Such support takes advantage of the 'Multimedia Principle'—the additive, parallel processing cognitive capabilities that are separately brought to play by presenting pictorial and verbal information together (Fletcher & Tobias, 2005; Mayer, 2001, 2006; Sweller, 2006). Graphical support in the form of navigation maps appears to be helpful, but as O'Neil, Wainess, and Baker (2005) point out, they can also add to cognitive load. Research is needed to settle this issue.

2b. Encourage Reflection About Correct Answers. Moreno and Mayer (2005) found that reflection about one's answers improved both near and far transfer, while interactivity (choosing a correct answer) improved only far transfer. They also found that reflection improved recall and far transfer without interactivity but not when interactivity was required, presumably because interaction had already facilitated participants' reflection. In a third experiment, reflection increased recall and far transfer; those reflecting on the program's (correct) solutions had a higher proportion correct and fewer wrong than those reflecting on their own (possibly incorrect) solutions. Guidance without reflection improved recall only marginally, but had a larger effect on transfer.

These results suggest that computer game designers should induce students to think about their answers by advising them to reflect about correct answers, by increasing their interactions with the program, or, finally, by giving them guidance. All of these practices seem likely to improve learning and transfer.

2c. Provide Guidance/Support for Discovery Learning. Findings on guidance reemphasize Mayer's (2004) conclusion that the state of evidence today should make anyone skeptical about the benefits of unsupported deductive discovery learning. Kirschner, Sweller, and Clark (2006; Sweller, Kirchner, & Clark, in press) extend this conclusion to all forms of minimally guided instruction (including such approaches as constructivist, problem-based, experiential, and inquiry based teaching). They note that research "has provided overwhelming and unambiguous evidence that minimal guidance during instruction is significantly less effective and efficient than guidance specifically designed to support the cognitive processing necessary for learning" (Kirschner *et al.*, 2006, p. 76).

There is an interaction between the level of prior knowledge and the value and type of guidance to be provided. Kalyuga, Ayres, Chandler, and Sweller (2003) summarized a number of studies in different fields demonstrating an "expertise reversal effect," indicating that high levels of instructional support are needed for novice learners but have little effect on experts and may actually interfere with their learning. Moreno (2005) also found that as learners become increasingly knowledgeable and capable with the subject matter, guidance may get in their way and in fact become annoying.

These interactions echo predictions (Tobias, 1989, 2003, 2005) that instructional support of all kinds is most important for students with limited prior knowledge of a domain. The interaction between prior learning and the provision of guidance seems particularly important when designing instructional games for adults, who are likely to be more task-oriented and more focused on what they need to learn than children. It also seems likely that a population of adult learners will bring a much wider spectrum of prior knowledge to any learning situation, including instructional games, than will children because of adults' more varied and extensive experience.

In sum, games relying on discovery learning should, especially for novices in the domains of interest, include instructional guidance and supports such as those discussed above. Ideally such support should be built into the games rather than being an "add on." Instructional support may be diminished gradually as learners' knowledge and mastery of the subject matter grow. Additional forms of support are discussed below.

3. *Use First Person in Dialogue.*

Moreno and Mayer (2000, 2004) found that including personal references to participants as part of a game, compared to neutral third person communication, increased learning and transfer. Their transfer measure consisted of questions not specifically covered in the materials. Attitudes to the material also improved with the inclusion of first person references. The results were similar whether communication with participants was in the form of speech or text, though attitudes to the game were not different for the speech version and only marginally more positive for the text format. Therefore, whenever possible designers should involve participants in first person ("I," "You") conversations, rather than the more impersonal third person.

It is unknown if including the name of participants, or other personal information, in dialogues is either equivalent to the use of the first person, or if it results in increased learning and/or more positive attitudes. While we did not locate computer game research dealing with this issue, research in mathematics instruction (Anand & Ross, 1987; Bracken, 1982; Herndon, 1987; Lopez, 1989, 1990; Ross & Anand, 1987; Wright & Wright, 1986) has shown that personalizing mathematical word problems by including students' names, their friends' and teachers' names, or including materials related to their interests improved performance and attitudes to the task. Designers of games could easily study this issue, by asking participants to provide their names or other non-sensitive personal information and then use it in the games. It would further be interesting to see if these findings applied equally to adult and non-adult learners. In any case, the research is needed and could be used to guide game design.

4. *Use Animated Agents in Interactions with Players.*

The use of animated instructional agents is an active area in developments dealing with computer based instruction, as can be seen from the special issue of this magazine devoted to that subject (Baylor, 2007). A number of articles in that issue describe the positive effects of agents on various computer based instructional programs, which are beyond the scope of the present paper. Maldonado and Nass (2007) represented a co-learner on screen "to determine the effects that learning alongside a social animate character has upon the student's performance and attitudes" (p. 34). They found that those who learned with an "emotive" co-learner on screen learned more than others without a co-learner or with an "unexpressive" co-learner. If replicated, this may be an interesting notion to apply to games as well.

Moreno, Mayer, Spires, and Lester (2001) found that having an animated instructional agent interact with students facilitated transfer and interest ratings but not retention. It should be relatively simple to develop such agents (avatars and/or cartoon characters) to interact with computer game players, rather than presenting instructions or other material in text format, or text augmented by audio. It is unclear whether the visual presence of the agent is actually necessary, since a number of studies (Moreno, 2005; Moreno & Flowerday, 2006) have shown that the spoken guidance offered by the agents is just as effective.

Baylor (2002) found that having an instructional agent (constructivist or an agent following instructional systems design principles) affected students' self reports of different processes, but had little effect on performance in an instructional planning task. Baylor noted that instructional planning was a less structured domain and more complex outcome than other tasks employed in similar research.

Dehn and Mulken (2000) reviewed the literature regarding the effectiveness of animated instructional agents on students' attitudes and their learning. They found that students rated systems with agents as being more entertaining than others, though the findings on other attitude variables (likeability, perceived intelligence, comfort, etc.) were less consistent. They also reported that attention was increased when an agent was present, though they cautioned that increased attention to the agent might decrease attention to the task. Finally, however, they concluded that results for improvement in learning due to the presence of an agent were inconclusive.

While the findings regarding use of an agent remain inconsistent, no study has shown that the visual presence of the agent interferes with learning. Furthermore, the most recent evidence suggests that agents are effective in making material more interesting (Moreno, 2005) and in improving learning. Therefore, it seems reasonable to include agents if possible—and affordable.

5. *Use Human, Not Synthetic Voices.*

Atkinson, Mayer, and Merrill (2005) found that using human as opposed to synthesized voices improved learning and transfer. It should be relatively simple to find and record good human speakers to give instructions, hints, feedback, and other material relevant to games, rather than to rely on synthetic speech. More research seems needed to verify this single study and to provide more guidance on when and how to use human voices in instructional computer games, but given a choice between human and synthetic speech, the former appears to have an edge over the latter.

6. *Maximize User Involvement.*

Wishart (1990) examined degree of challenge, control, and complexity in a study of 300 children (mean age just below nine) and found that learner involvement increased most when players had more control of the game. Complexity and challenge added singly to control did not increase learner involvement, though they did when added jointly. Increased learner involvement was also shown to increase posttest scores.

Similarly, Fletcher (2004), in reviewing hundreds of studies concerning the use of computer-based instruction, found that a major factor accounting for successful applications was the intense, frequent interactivity enabled by computer technology applied in instructional environments. Such interactivity enhances user involvement, is characteristic of computer games, and should be emphasized in the design of computer games used to provide instruction. When game designers have a choice between a passive display, or an interactive one, the latter seems more likely to increase learning.

There is a good deal of research dealing with learner control in the field of computer-based instruction, and in instructional research more generally. Clark (2004, p. 25) summarizes the results of that research by saying: "As the extent of learner control increases, learning decreases except for the most advanced expert learners." Lunts (2002) also reviewed the literature dealing with learner control of instruction and found largely inconsistent and contradictory findings regarding its effect on learning, and suggested that such control be implemented with caution. Of course, it is not clear that these finding also apply to learner control in computer games, though both Clark's and Lunts' findings suggest that some caution about these effects may be appropriate.

7. *Reduce Cognitive Load.*

Computer games can be very demanding of participants' cognitive capabilities. Mayer, Mautone, and Prothero (2002) simulated a cognitive apprenticeship by using tasks that geographers perform, specifically the need to reason about geographic issues based on visual data. They found, as mentioned above, that using pictorial guidance improved participants' performance, presumably because the cognitive demands were reduced. Again, this finding seems due to the additive parallel processing posited by the Multimedia Principle as discussed by Fletcher and Tobias (2005), Mayer (2001, 2006), and Sweller (2006). Navigation maps have the potential to reduce cognitive load, but, as O'Neil *et al.* (2005) point out, they may also add to it. Again, resolution of this issue awaits more empirical findings.

Game players often have to select among many choices, recall game rules and prior moves, and/or weigh various alternate strategies. Such activities may exceed their cognitive capacities, especially those of working memory. Designers should keep these considerations in mind during game development. When the games place especially high demands on players, instructional guidance and supports—such as those discussed above—should be used to reduce the cognitive load.

8. *Maximize Motivation.*

A general finding in the literature has been that students enjoy playing computer games. (Lepper & Malone, 1987; Malone, 1981a, b; Malone & Lepper, 1987) described some of the game characteristics that enhance motivation. For example, games should include an appropriate level of challenge, they should arouse curiosity, give students appropriate control (responsive, choices, large effects), and include fantasy elements that appeal to users. Therefore, designers should empahsize such elements in computer games used for instruction. Moreover, the features intended to arouse motivation should be integral to the game. Research by Wade and Adams (1990) and Schraw (1998) on learning from text has found that adding highly interesting elements ('seductive details') that are not related to task objectives can actually reduce mastery of the material's intended objectives, at the expense of the seductive details which are easily recalled.

9. *Increase Pro-social Content and Reduce Aggression.*

There is quite a bit of aggressive content in many computer games. In view of the general popularity of gaming, that is of some concern, since meta-analyses (Anderson & Bushman, 2001) have shown that players of aggressive games manifest more aggression and hostility. Anderson and Dill's (2000) experimental and self-report findings strengthen that conclusion. In a thoughtful review of the literature dealing with the effect of games on aggression, Gentile (2005) concluded that despite major design flaws in some studies "given the preponderance of evidence from all types of studies (experimental, cross-sectional, l ongitudinal, and meta-analytic), it seems reasonable to conclude that violent video games do indeed have an effect on aggression" (p. 17), i.e., they increase it. It should be noted that the age range of participants in studies reviewed by Gentile was from elementary school to college undergraduates, suggesting that these findings are not limited by age.

Theses results suggest that designers of computer games should try to reduce aggressive content. It should also be noted that including pro-social content was found to be effective by Fontana and Beckerman (2004). Presumably, such content should increase pro-social behaviors and also reduce aggressive behaviors. Therefore, game designers should try to include such pro-social content in their products.

10. *Revise Games and Task Analyses.*

If the task analyses of the computer game and learning objective(s) indicate that there is no overlap between them, one or both need to be revised or modified. Hays (2005) suggested that, after learning objective(s) and game processes are reviewed, it may be necessary to design or modify the games by changing their design and/or by providing different forms of instructional support in order to achieve the targeted learning objectives. O'Neil *et al.* (2005) discuss two models, Kirkpatrick's (1994) and their own, to use in such reviews of the instructional effectiveness of games. Unfortunately, as Squire (2005) reported, few game development teams include instructional design expertise. In the absence of such expertise, game players may fail to achieve the learning objectives, even though they may acquire a good deal of game-relevant knowledge and capabilities.

It cannot be assumed that capabilities developed by "off the shelf" computer games that are not specifically designed to transfer to a real-life task will actually transfer to that task. As indicated above, the research is clear that one may *not* assume the occurrence of transfer merely from superficial similarities of appearances between task and the game. Furthermore, if preliminary outcomes from the game indicate that there is little learning, revisions are in order along the lines suggested above. Design should be viewed more as a process than as a single episodic event.

11. *Integrate Games with Instructional Objectives and Other Instruction.*

Games intended for instruction rarely exist in a vacuum. It is important that the games should be integrated into existing instructional or training programs (Hays, 2005). Leutner (1993) found that students learn procedures that are useful in the game, but they do not necessarily acquire more general competencies. It therefore becomes important to direct the attention of students to the curricular or task objectives they are to acquire from the game. This seems likely to be as applicable among adults as among children.

12. *Keep Abreast of Emerging Research Findings.*

Research on instructional use of computer games is volatile and rapidly evolving. Some of the recommendations made above may need to be modified in the light of continuing research. Given the complexity of human beings and the changing demands made upon them by schools and the workplace (Funk & McBride, 2000; Quiñones & Ehrenstein, 1996), it is quite likely that some recommendations will not be verified by succeeding research and will have to be changed. Joining O'Neil *et al.* (2005), we recommend that designers of games intended for instruction should keep abreast of research findings so that their products continue to be useful.

The emphasis on processes underlying performance in computer games and everyday tasks fits well with research in a number of areas. For example, Clark (1983, 2001; Sugrue & Clark, 2000) has argued that varying media in instructional presentations has little effect on learning unless the use of varying media engages alternative cognitive processes that control learning. This position builds on one advanced previously (Tobias, 1982, 1989, 2003), which suggested that varying instructional methods leads to different outcomes only if the alternative methods engage different cognitive processes, or if one method leads to more intensive processing than another. This emphasis on process is consonant with much of the research in cognitive psychology.

13. *Use Teams to Develop Instructional Games.*

The above recommendations imply that the design of computer games for instruction should be a team process. Obviously, individuals with expertise in game design, cognitive task analysis, and instructional systems design should be part of such teams. However, it is also important—as suggested above—that members of these teams be familiar with emerging research results about the effects of games on learning. Such varied expertise does not usually occur in one person. Consulting with experts familiar with the different fields not represented on the team during the development process should help maximize the learning outcomes of computer games, and presumably their profitability as well.

Table 2. Summary of recommendations for the design of games and simulations.

	Recommendation	**Supporting Studies & Reviews**
1	Conduct cognitive task analysis to identify the cognitive processes engaged by game and required by task.	Brown *et al.*, 1997; Fery & Ponserre, 2001; Gopher *et al.*, 1994; Green & Bavelier, 2003; Greenfield, 1998; Greenfield, Brannon *et al.*, 1994; Greenfield, Camaioni *et al.*, 1994; Greenfield, deWinstanley *et al.*, 1994; Mayer *et al.*, 2002; Moreno & Mayer, 2004, 2005; Okagaki & Frensch, 1994; Rosser *et al.*, 2007; Sims & Mayer, 2002; Subrahmanyam & Greenfield, 1994.
2	Provide guidance: (2a) Provide pictorial support.	Fletcher & Tobias, 2005; Greenfield, Camaioni *et al.*, 1994; Kalyuga, Ayres, Chandler, & Sweller 2003; Lee, 1999; Mayer, 2001, 2006; Mayer *et al.*, 2002; Moreno, 2005; Moreno & Mayer, 2005; Rieber, 2005; Swaak & de Jong, 2001; Sweller 2006.
	(2b) Encourage reflection about correct answers.	Moreno, 2005; Moreno & Mayer, 2005.
	(2c) Provide guidance/support for discovery learning.	Kirschner, Sweller, & Clark, 2006; Mayer, 2004; Swaak & de Jong, 2001.
3	Use first person in dialogue.	Moreno & Mayer, 2000, 2004.
4	Use animated agents in interactions with players	Baylor, 2002; Moreno, 2005; Moreno & Flowerday, 2006; Moreno, Mayer, Spires, & Lester, 2001.
5	Use human, not synthetic voices.	Atkinson, Mayer, & Merrill, 2005.
6	Maximize user involvement.	Fletcher, 2004; Wishart, 1990.
7	Reduce cognitive load.	Kirchner *et al.*, 2006; Mayer, Mautone, & Prothero, 2002; Sweller, 2006.
8	Maximize motivation.	Lepper & Malone, 1987; Malone, 1981a, b; Malone & Lepper, 1987.
9	Increase pro-social content and reduce aggression.	Anderson & Bushman, 2001; Anderson & Dill, 2000; Fontana & Beckerman, 2004; Gentile, 2005.
10	Revise games and task analyses.	Hays, 2005; O'Neil, Wainess, & Baker, 2005.
11	Integrate games with instructional objectives and other instruction.	Leutner, 1993.
12	Keep abreast of emerging research findings.	O'Neil, Wainess, & Baker, 2005.
13	Use teams to develop instructional games.	Squire, 2005.

Final Word

Table 2 summarizes our recommendations. Specific supporting studies are not included for recommendations 10 and 12, though they were supported by some reviews or research and inferred from the studies examined.

As researchers, it would be unusual for us to conclude without a call for more research. We do not intend to break with tradition. One area of research seems particularly important to us. We note that the need to acquire game-relevant competencies in order to achieve instructional objectives can increase game learning time and effort over more direct non-game instructional approaches. The emphasis in games on story lines, competition, and even fantasy can also distract learners from the pursuit of targeted instructional objectives. An assumption underlying the development and use of instructional games is that inefficiencies of this sort may be more than compensated by the greater amount of time and effort learners may be willing, perhaps eager, to expend playing a game compared to the time and effort they might devote to more direct instruction. This trade-off between the time learners may be motivated to spend in the learning environment (game or non-game) and the 'efficiency' of the learning environment (the amount of time required to achieve learning objectives) has yet to be systematically assessed by research. It remains an interesting and possibly decisive issue in the use of games for learning. More research on this issue is needed. □

References

Anand, P. G., & Ross, S. M. (1987). Using computer-assisted instruction to personalize arithmetic materials for elementary school children. *Journal of Educational Psychology, 79*, 72–78.

Anderson, C. A., & Bushman, B. J. (2001). Effects of violent video games on aggressive behavior, aggressive cognition, aggressive affect, physiological arousal, and prosocial behavior: A meta-analytic review of the scientific literature. *Psychological Science, 12*, 353–359.

Anderson, C. A., & Dill, K. (2000). Video games and aggressive thoughts, feelings, and behavior in the laboratory and in life. *Journal of Personality and Social Psychology, 78*, 772–790.

Andrews, D. H., & Bell, H. H. (2000). Simulation based training. In S. Tobias & J. D. Fletcher (Eds.), *Training and retraining: A handbook for business, industry, government, and the military* (pp. 357–384). New York: Macmillan.

Atkinson, R. K., Mayer, R. E., & Merrill, M. M. (2005). Fostering social agency in multimedia learning. Examining the impact of an animated agent's voice. *Contemporary Educational Psychology, 30*, 117–139.

Baylor, A. L. (2002). Expanding pre-service teachers' metacognitive awareness of instructional planning. *Educational Technology Research and Development, 50*, 5–22.

Baylor, A. (2007). Introduction to special issue on pedagogical agents. *Educational Technology, 47*(1), 3–4.

Blaiwes, A. S., & Regan, J. J. (1986). Training devices: Concepts and progress. In J. A. Ellis (Ed.), *Military contributions to instructional techology* (pp. 83–170). New York: Praeger.

Bracken, B. A. (1982). Effect of personalized basal stories on the reading comprehension of fourth grade poor and average readers. *Contemporary Educational Psychology, 7*, 320–324.

Brown, S. J., Lieberman, D. A., Gemeny, B. A., Fan, Y. C., Wilson, D. M., & Pasta, D. J. (1997). Educational video games for juvenile diabetes: Results for a controlled trial. *Medical Informatics, 22*, 77–89.

Clark, J. A., Volchok, J. A., Hazey, J. W., Sadighi, P. J., & Fanelli, R. D. (2005). Initial experience using an endoscopic simulator to train surgical residents in flexible endoscopy in a community medical center residency program. *Current Surgery, 62*, 59–63.

Clark, R. E. (1983). Reconsidering research on learning from media. *Review of Educational Research, 53*, 445–459.

Clark, R. E. (Ed.). (2001). *Learning from media: Arguments, analysis, and evidence*. Greenwich, CT: Information Age Publishing.

Clark, R. E. (2004). Instructional strategies, In H. F. O'Neil (Ed.), *What works in distance learning: Guidelines* (pp. 25–39). Greenwich, CT: Information Age Publishing.

Clark, R. E. (2007). Learning from serious games? Arguments, evidence, and research suggestions. *Educational Technology, 47*(3), 56–59.

Colt, H. G., Crawford, S. W., & Galbraith, O. (2001). Virtual reality bronchoscopy simulation: A revolution in procedural training. *Chest, 120*, 1333–1339.

Crandall, B., Klein, G., & Hoffman, R. R. (2006). *Working minds: A practitioner's guide to cognitive task analysis.* Cambridge, MA: MIT Press (Bradford Books).

Dehn, D., & van Mulken, S. (2000). The importance of animated interfact agents: *A review of empirical research. International Journal of Human-Computer Studies, 52*, 1–22.

Entertainment Software Association. (2006a). *Game player data; http://www.theesa.com/facts/gamer_data.php* .

Entertainment Software Association. (2006b). *Top ten industry facts; http://www.theesa.com/facts/top_10_facts.php* .

Fery, Y. A., & Ponserre, S. (2001). Enhancing the control of force in putting by video game training. *Ergonomics, 44*, 1025–1037.

Fletcher, J. D. (2004). Technology, the Columbus effect, and the third revolution in learning (pp. 139–157). In M. Rabinowitz, F. C. Blumberg, & H. Everson (Eds.), *The design of instruction and evaluation: Affordances of using media and technology.* Mahwah, NJ: Lawrence Erlbaum Associates.

Fletcher, J. D., & Tobias, S. (2005). The multimedia principle. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (pp. 117–133). New York: Cambridge University Press.

Fontana, L., & Beckerman, A. (2004). Childhood violence prevention education using video games. *Information Technology in Childhood Education Annual, 16*, 49–62.

Funk, S. L., & McBride, D. (2000). Training in the twenty-first century. In S. Tobias & J. D. Fletcher (Eds.), *Training and* *retraining: A handbook for business, industry, government, and the military* (pp. 550–570). New York: Macmillan.

Gallagher A. G., Lederman, A. B., McGlade, K., Satava, R. M., & Smith, C. D. (2004). Discriminative validity of the Minimally Invasive Surgical Trainer in Virtual Reality (MIST-VR) using criteria levels based on expert performance. *Surgical Endoscopy, 18*, 660–665.

Gallagher, A. G., Ritter, E. M., Champion, H., Higgins, G., Fried, M. P., Moses, G., Smith, C. D., & Satava, R. M. (2005). Virtual reality simulation for the operating room: Proficiency-based training as a paradigm shift in surgical skills training. *Annals of Surgery, 241*, 364–372.

Gallagher, A. G., & Smith, C. D. (2003). From the operating room of the present to the operating room of the future: Human-factors lessons learned from the minimally invasive surgery revolution. *Seminars in Laparoscopic Surgery, 10*, 127–139.

Gentile, D. A. (2005). *Examining the effects of video games from a psychological perspective: Focus on violent games and a new synthesis.* Ames: Iowa State University; *http://www.mediafamily.org/research/Gentile_NIMF_Review_2005.pdf* .

Gopher, D., Weil, M., & Bareket, T. (1994). Transfer of skill from a computer game trainer to flight. *Human Factors, 36*, 387–405.

Gott, S. P., & Lesgold, A. M. (2000). Competence in the workplace: How cognitive performance models and situated instruction can accelerate skill acquisition. In R. Glaser (Ed.), *Advances in instructional psychology* (pp. 239–327). Hillsdale, NJ: Lawrence Erlbaum Associates.

Green, C. S., & Bavelier, D. (2003). Action video game modifies visual selective attention. *Nature, 423*, 534–537.

Greenfield, P. M. (1998). The cultural evolution of IQ. In U. Neisser (Ed.), *The rising curve: Long-term gains in IQ and related measures* (pp. 81–123). Washington, DC: American Psychological Association.

Greenfield, P. M., Brannon, C., & Lohr, D. (1994). Two-dimensional representation of movement through three-dimensional space: The role of video game expertise. *Journal of Applied Developmental Psychology, 15*, 87–103.

Greenfield, P. M., Camaioni, L., Ercolani, P., Weiss, L., & Lauber, B. A. (1994). Cognitive socialization by computer games in two cultures: Inductive discovery or mastery of an iconic code. *Journal of Applied Developmental Psychology, 15*, 59–85.

Greenfield, P. M., deWinstanley, P., Kilpatrick, H., & Kaye, D. (1994). Action video games and informal education: Effects on strategies for dividing visual attention. *Journal of Applied Developmental Psychology, 15*, 195–223.

Hall, E. P., Gott, S. P., & Pokorny, R. A. (1996). *A procedural guide to cognitive task analysis: The PARI Methodology* (AL/HR-TR-1995-0108). San Antonio, TX: Brooks Air Force Base.

Hamilton, E. C., Scott D. J., & Kapoor A. *et al.* (2001). Improving operative performance using a laparoscopic hernia simulator. *American Journal of Surgery, 182*, 725–728.

Hart, S. G., & Battiste, V. (1992). Flight test of a video game trainer. In *Proceedings of the Human Factors Society 36th Annual Meeting* (pp. 1291–1295). Santa Monica, CA: Human Factors and Ergonomics Society.

Hays, R. T. (2005). *The effectiveness of Instructional games: A literature review and discussion* (Technical report 2005-004). Orlando, FL: Naval Air Warfare Center.

Herndon, J. N. (1987). Learner interests, achievement, and continuing motivation in instruction. *Journal of Instructional Development, 10*, 11–14.

International Game Developers Association. (2005). Breaking in, preparing for your career in games; *http://www.igda.org/breakingin/resource_schools.php* .

Kirkpatrick, D. L. (1994). *Evaluation training programs: The four levels.* San Francisco: Berrett-Koehler.

Kalyuga, S., Ayres, P., Chandler, P., & Sweller, J. (2003). The expertise reversal effect. *Educational Psychologist, 38*, 23–31.

Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry based teaching. *Educational Psychologist, 41*, 75–86.

Lee, J. (1999). Effectiveness of computer-based instructional simulation: A meta-analysis. *International Journal of Instructional Media, 26*(1), 71–85.

Lepper, M. R., & Malone, T. W. (1987). Intrinsic motivation and instructional effectiveness in computer-based education. In R. E. Snow & M. J. Farr (Eds.), *Aptitude, learning, and instruction volume 3: Conative and affective process analyses* (pp. 255–286). Hillsdale, NJ: Lawrence Erlbaum Associates.

Leutner, D. (1993). Guided discovery learning with computer-based simulation games: Effects of adaptive and non-adaptive instructional support. *Learning and Instruction, 3*, 113–132.

Lopez, C. I. (1989). *Effects of personalized math instruction for Hispanic students.* Paper presented at the annual convention of the American Educational Research Association, San Francisco.

Lopez, C. I. (1990). *Personalizing math word problems.* Proceedings of selected paper presentations at the convention of the Association for Educational Communications and Technology.

Lunts, E. (2002). What does the literature say about the effectiveness of learner control in computer-assisted instruction? *Electronic Journal for the Integration of Technology in Education, 1*, 59–75; *http://ejite.isu.edu/Volume1No2/Lunts.pdf>http://ejite.isu.edu/Volume1No2/Lunts.pdf* .

Maldonado, H., & Nass, C. (2007). Emotive characters can make learning more productive and enjoyable: *It takes two to learn to tango. Educational Technology, 47*(1), 33–38.

Malone, T. W. (1981a). What makes computer games fun? *Byte, 6*, 258–277.

Malone, T. W. (1981b). Toward a theory of intrinsically motivating instruction. *Cognitive Science, 4*, 333–369.

Malone, T. W., & Lepper, M. R. (1987). Making learning fun: A taxonomy of intrinsic motivation for learning. In R. E. Snow & M. J. Farr (Eds.), *Aptitude, learning, and instruction volume 3: Conative and affective process analyses* (pp. 223–253). Hillsdale, NJ: Lawrence Erlbaum Associates.

Mane, A., & Donchin, E. (1989). The *Space Fortress* game. *Acta Psycholgica, 71*, 17–22.

Mayer, R. E. (2001). *Multimedia learning.* New York: Cambridge University Press.

Mayer, R. E. (2004). Should there be a three strike rule against pure discovery learning? *American Psychologist, 59*, 14–19.

Mayer, R. E. (2006). Ten research-based principles of multimedia learning. In H. F. O'Neil, Jr., & R. S. Perez (Eds.), *Web-based learning: Theory, research, and practice* (pp. 371–390). Mahwah, NJ: Lawrence Erlbaum

Associates.
Mayer, R. E., Mautone, P., & Prothero, W. (2002). Pictorial aids for learning by doing in a multimedia geology simulation game. *Journal of Educational Psychology, 94*, 171–185.
Moreno, R. (2005). Multimedia learning with animated pedagogical agents. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (pp. 507–523). New York: Cambridge University Press.
Moreno, R., & Flowerday, T. (2006). Students' choice of animated pedagogical agents in science learning: A test of the similarity-attraction hypothesis on gender and ethnicity. *Contemporary Educational Psychology, 31*, 186–207.
Moreno, R., & Mayer, R. E. (2000). Engaging students in active learning: The case for personalized multimedia messages. *Journal of Educational Psychology, 92*, 724–733.
Moreno, R., & Mayer, R. E. (2004). Personalized messages that promote science learning in virtual environments. *Journal of Educational Psychology, 96*, 165–173.
Moreno, R., & Mayer, R. E. (2005). Role of guidance, reflection, and interactivity in an agent-based multimedia game. *Journal of Educational Psychology, 97*, 117–128.
Moreno, R., Mayer, R. E., Spires, H. A., & Lester, H. A. (2001). The case for social agency in computer-based teaching: Do students learn more deeply when they interact with animated pedagogical agents? *Cognition and Instruction, 19*, 177–213.
O'Neil, H. F., & Robertson, M. M. (1992). Simulations: Occupationally oriented. In M. C. Alkin (Ed.), *Encyclopedia of educational research* (6th ed.) (pp. 1216–1222). New York: Macmillan.
O'Neil, H. F., Wainess, R., & Baker, E. L. (2005). Classification of learning outcomes: Evidence from the computer games literature. *The Curriculum Journal, 16*, 455 – 474.
Okagaki, L., & Frensch, P. A. (1994). Effects of video game playing on measures of spatial performance: Gender effects in late adolescence. *Journal of Applied Development Psychology, 15*, 33–58.
Pedowitz, R. A., Esch, J., & Snyder, S. (2002). Evaluation of a virtual reality simulator for arthroscopy skills development. *Arthroscopy, 18*, E29.
Quiñones, M. A., & Ehrenstein, A. (Eds.). (1996). *Training for a rapidly changing workplace: Applications of psychological research.* Washington, DC: American Psychological Association.
Randel, J. M., Morris B. A., Wetzle, C. D., & Whitehill, B. V. (1992). The effectiveness of games for educational purposes: A review of recent research. *Simulation and Gaming, 23*, 261–276.
Renkl, A., & Atkinson, R. (2003). Structuring the transition from example study to problem solving in cognitive skill acquisition: A cognitive load perspective. *Educational Psychologist, 38*, 15–22.
Rieber, L. P. (2005). Multimedia learning in games, simulations, and microworlds. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (pp. 549–567). New York: Cambridge University Press.
Ross, S. M., & Anand, P. G. (1987). A computer based strategy for personalizing verbal problems in teaching mathematics. *Educational Communications and Technology Journal, 35*, 151–162.
Rosser, J. C., Jr., Lynch, P. J., Cuddihy, L., Gentile, D. A., Klonsky, J., & Merrell, R. (2007). The impact of video games on training surgeons in the 21st century. *Archives of Surgery, 142*, 181–186.
Schiesel, S. (2007). Another world conquered by video games: Retirees. *New York Times, 156*(CLVI), No. 53899, p. A21.
Schraw, G. (1998). Processing and recall differences among seductive details. *Journal of Educational Psychology, 90*, 3–12.
Schraagen, J. M., Chipman, S. F., & Shalin, V. L. (Eds.). (2000). *Cognitive task analysis.* Mahwah, NJ: Lawrence Erlbaum Associates.
Sims, V. K., & Mayer, R. E. (2002). Domain specificity of spatial expertise: The case of video game players. *Applied Cognitive Psychology, 16*, 97–115.
Squire, K. (2005). Game-based leaning: Present and future state of the field. Masie Center e-Learning Consortium; *http://www.masie.com/xlearn/Game-Based_Learning.pdf* .
Subrahmanyam, K., & Greenfield, P. M. (1994). Effect of video game practice on spatial skills in girls and boys. Special Issue: Effects of interactive entertainment technologies on development. *Journal of Applied Developmental Psychology, 15*, 13–32.
Sugrue, B., & Clark, R. E. (2000). Media selection for training. In S. Tobias & J. D. Fletcher (Eds.), *Training and retraining: A handbook for business, industry, government, and the military* (pp. 208–234). New York: Macmillan.
Swaak, J., & de Jong, T. (2001). Discovery simulations and the assessment of intuitive knowledge. *Journal of Computer Assisted Learning, 17*, 284–294.
Sweller, J. (2006). Why understanding instructional design principles requires an understanding of the evolution of human cognitive architecture. In H. F. O'Neil, Jr., & R. S. Perez (Eds.), *Web-based learning: Theory, research, and practice* (pp. 279–294). Mahwah, NJ: Lawrence Erlbaum Associates.
Sweller, J., Kirchner, P. A., & Clark, R. E. (in press). Why minimally guided teaching techniques do not work: A reply to commentaries. *Educational Psychologist.*
Tobias, S. (1982). When do instructional methods make a difference? *Educational Researcher, 11*(4), 4–9.
Tobias, S. (1989). Another look at research on the adaptation of instruction to student characteristics. *Educational Psychologist, 24*, 213–227.
Tobias, S. (2003). Extending Snow's conceptions of aptitudes. *Contemporary Psychology, 48*, 277–279.
Tobias, S. (2005). *Instructional innovations, adaptive instruction, and Advanced Distributed Learning.* Paper presented at the annual convention of the American Educational Research Association, Montreal.
Towne, D. M. (1995). *Learning and instruction in simulated environments.* Englewood Cliffs, NJ: Educational Technology Publications.
Wade, S. E., & Adams, R. B. (1990). Effects of importance and interest on recall of biographical text. *Journal of Reading Behavior, 22*, 330–353.
Wishart, J. (1990). Cognitive factors related to user involvement with computers and their effects upon learning from an educational computer game. *Computers and Education, 15*(1–3),145–150.
Wright, J. P., & Wright, C. D. (1986). Personalized verbal problems. An application of the language experience approach. *Journal of Educational Research, 79*, 358–362.